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Final Report

SENSING OF REMOTE EM SOURCES (PHYSIOLOGICAL CORRELATES)

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Prepared for:

NAVAL ELECTRONICS SYSTEMS COMMAND
WASHINGTON, D.C. 20360

Attention: MR. JAMES FOOTE
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*Final Report
Covering the Period November 1975 to October 1976*

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SRI Project 4540

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PART ONE: SRI ANALYSIS

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I INTRODUCTION AND SUMMARY

A. Introduction

The objective of the program reported here was to investigate the characteristics of, and, if possible, determine the mechanisms responsible for, the coupling of remote electromagnetic stimuli to human detection modalities, utilizing physiological response (specifically, EEG) as an indication of such registration.

In a number of laboratories evidence has been obtained indicating the existence of an as-yet-unidentified channel wherein information is coupled from remote electromagnetic stimuli to the human nervous system, as indicated by physiological responses. This coupling can be measured, even though overt subject responses such as verbalizations or pressing of a key provide no evidence for such information transfer. Physiological measures have included plethysmographic response¹* and EEG activity.^{2,3} Kamiya, Lindsley, Pribram, Silverman, Walter, and others have suggested that a whole range of EEG responses such as evoked potentials (EPs), spontaneous EEG, and the contingent negative variation (CNV) might be sensitive indicators of the detection of remote stimuli not mediated by usual sensory processes.⁴

A pilot study was therefore undertaken at SRI to determine whether EEG activity could be used as a reliable indicator of information transmission between an isolated subject and a remote stimulus. Following earlier work of others, we assumed that perception could be indicated by such a measure even in the absence of verbal or other overt indicators.

To aid in selecting a stimulus, we noted that Silverman and Buchsbaum attempted, without success, to detect EP changes in a subject in response to a single stroboscopic flash stimulus per trial observed by another subject.⁵ Kamiya suggested that because of the unknown temporal characteristic of the information channel, it might be more

* References are listed at the end of this report.

appropriate to use repetitive bursts of light to increase the probability of detecting information transfer.⁶ Therefore, in our study we chose to use repetitive light bursts as stimuli.⁷⁻⁹

B. Summary

In Section II we describe the pilot study conducted at SRI, which led to the present investigation. It was in this study that we obtained our first indication that remote light-flash stimuli could cause systematic changes in the observed EEG production of an individual shielded against direct perception of the light.

Section III presents the technical approach employed in the most recent investigations. This includes a description of the battery-operated strobe light equipment, shielding precautions, experimental protocol, and finally data analysis.

Section IV presents a detailed discussion of the results from all phases of the study.

Part Two of this report is the technical evaluation prepared for us by our independent consultants at Langley Porter Neuropsychiatric Institute. In their report they analyze the present investigation from the point of view of practicing perceptual psychologists.

In the Appendix to this report we describe the optical measurements made to determine the extent of possible light leakage from the stimulus room to the subject room.

II PILOT STUDY AT SRI

In the design of the study it was assumed that the application of remote stimuli might result in responses similar to those obtained under conditions of direct stimulation. For example, when normal subjects are stimulated with a flashing light, their EEG typically shows a decrease in the amplitude of the resting rhythm and a driving of the brain waves at the frequency of the flashes.¹⁰ We hypothesized that if we stimulated one subject in this manner (a putative sender), the EEG of another subject in a remote room with no flash present (a receiver)

might show changes in alpha (8 to 13 Hz) activity, and possibly EEG driving similar to that of the sender, either by means of coupling to the sender's EEG, or by coupling directly to the stimulus.

We informed our subject that at certain times a light was to be flashed in a sender's eyes in a distant room, and if the subject perceived that event, consciously or unconsciously, it might be evident from changes in his EEG output. The receiver was seated in a visually opaque, acoustically and electrically shielded double-walled steel room located approximately 7 m from the sender's room.

We initially worked with four female and two male volunteer subjects. These were designated "receivers." The senders were either other subjects or the experimenters. We decided beforehand to run one or two sessions of 36 trials with each subject in this selection procedure, and to do a more extensive study with any subject whose results were positive.

A Grass PS-2 photostimulator placed about 1 m in front of the sender was used to present flash trains of 10 s duration. The receiver's EEG activity from the occipital region (Oz), referenced to linked mastoids, was amplified with a Grass 5P-1 preamplifier and associated driver amplifier with a bandpass of 1 to 120 Hz. The EEG data were recorded on magnetic tape with an Ampex SP300 recorder.

On each trial, a tone burst of fixed frequency was presented to both sender and receiver and was followed in one second by either a 10-s train of flashes or a null flash interval presented to the sender. Thirty-six such trials were given in an experimental session, consisting of 12 null trials--no flashes following the tone--12 trials of flashes at 6 flashes per second (fps) and 12 trials of flashes at 16 fps, all randomly intermixed, determined by entries from a table of random numbers. Each of the trials consisted of an 11-s EEG epoch. The last 4 s of the epoch were selected for analysis to minimize the desynchronizing action of the warning cue. This 4-s segment was subjected to Fourier analysis on a LINC 8 computer.

Spectrum analyses gave no evidence of EEG driving in any receiver, although in control runs the receivers did exhibit driving when physically stimulated with the flashes. But of the six subjects studied initially, one subject showed a consistent alpha blocking effect. We therefore undertook further study with this subject. We note that of our six subjects, this one had the most monochromatic EEG spectrum. Figure 1 shows a typical occipital EEG spectrum of this subject.

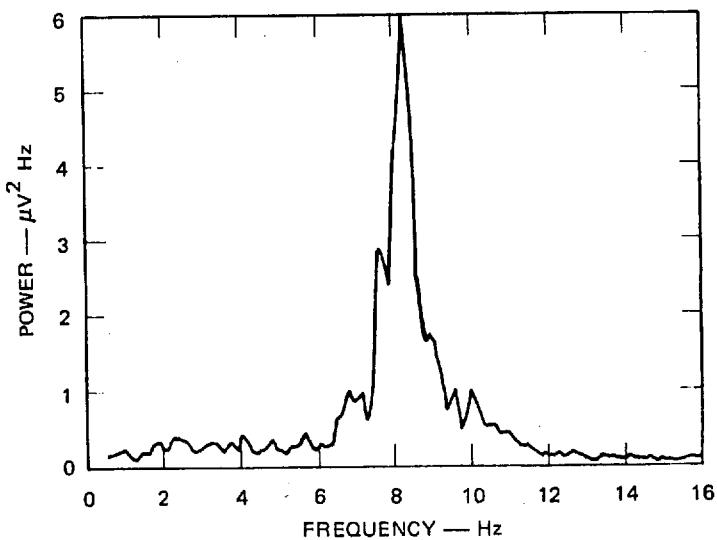


FIGURE 1 TYPICAL POWER SPECTRUM AVERAGED OVER TWENTY 8-SECOND EPOCHS FOR ONE SUBJECT

Data from seven sets of 36 trials each were collected from this subject on three separate days. This comprised all the data collected to date with this subject under the test conditions described above. The alpha band was identified from average spectra; then scores of average power and peak power were obtained from individual trials and subjected to statistical analysis. The final analysis showed that power values were less in the 16-fps case than in the 0-fps case (no light) in all seven sets of peak power measurements and in six out of seven average-power measurements.

Siegel's two-tailed *t* approximation to the nonparametric randomization test¹¹ was applied to the data from all sets, which included two

sessions in which the sender was removed. Average power during trials associated with the occurrence of 16 fps was significantly less than when there were no flashes ($t = 2.09$, $df = 118$, $p < 0.04$). The second measure, peak power, was also significantly less in the 16-fps conditions than in the null condition ($t = 2.16$, $df = 118$, $p < 0.03$). The response in the 6-fps condition was in the same direction as that associated with 16 fps, but the effect was not statistically significant.

As part of the experimental protocol for each trial, the subject was asked to indicate conscious assessment as to which stimulus was generated. The guess was registered by the subject via one-way telegraphic communication. An analysis of these guesses has shown them to be at chance, indicating the absence of any supraliminal cueing, so arousal as evidenced by significant alpha blocking occurred only at the noncognitive level of awareness.

Several control procedures were undertaken to determine if these results were produced by system artifacts or by subtle cueing of the subject. Low-level recordings were made from saline of 12-kilohm resistance in place of the subject, with and without the introduction of 10-Hz, 50- μ V signals from a battery-operated generator. The standard experimental protocol was adhered to and spectral analysis of the results were carried out. There was no evidence in the spectra associated with the flash frequencies, and the 10-Hz signal was not perturbed.

In another control procedure a five-foot pair of leads was draped across the subject's chair (subject absent). The leads were connected to one input of a C.A.T. 400C "averager." Two-second sweeps, triggered at onset of the tone, were taken once every 13 s for approximately two hours, for about 550 samples. No difference in noise level between the fore-period and the onset of flicker was observed.

III TECHNICAL APPROACH

A. Replication Studies at Langley Porter

The main effort of the program was directed toward replication, by an independent laboratory, of the original SRI study of EEG response

to remote strobe-light stimuli. Arrangements for replication were made with the Langley Porter Neuropsychiatric Institute, University of California Medical Center, San Francisco. Dr. David Galin and Dr. Robert Ornstein were our principal consultants.

As a special precaution against the possibility of system artifacts in the form of electromagnetic pickup from the strobe-light discharge or associated electronic equipment (e.g., through the power lines), SRI developed an entirely-battery-operated package for use as a stimulus generator for the EEG experimentation. It consists of a battery-driven incandescent lamp, whose CW output passes through a mechanical chopper continuously driven by a battery-powered motor as shown in Figure 2. A 10-Hz timing generator (computer triggered) controls the generation of a 1-kHz warning tone 2 s before onset of the experimental period, and also drives a locking circuit that determines the presence or absence of the 10-s light stimulus, again all battery operated. Thus everything on the left of the diagram of Figure 2 is battery operated and therefore independent of the power-line system. Further, the arc-discharge strobe lamp was replaced by an incandescent lamp to eliminate the possibility of direct subliminal pickup of audio or electrical signals from possible transients associated with the arc discharge or associated electronics.

Finally, the possibility of artifact due to light-leakage between the lamp (stimulus) and subject (receiver) was investigated by the use of a photomultiplier in conjunction with a phase-sensitive detection system. The results, presented in detail in the Appendix, indicated no light leakage between the rooms in question to the limit of our measurement capability (125 dB attenuation).

1. Description of the EEG Processor

A hardware single-channel power spectrum analyzer was constructed from a commercial bandpass filter with corner frequencies of 9.0 and 12.0 Hz, and a roll-off 48 dB down at 8.0 and 13.0 Hz. Analog multipliers convert the filter output to a signal proportional to in-band

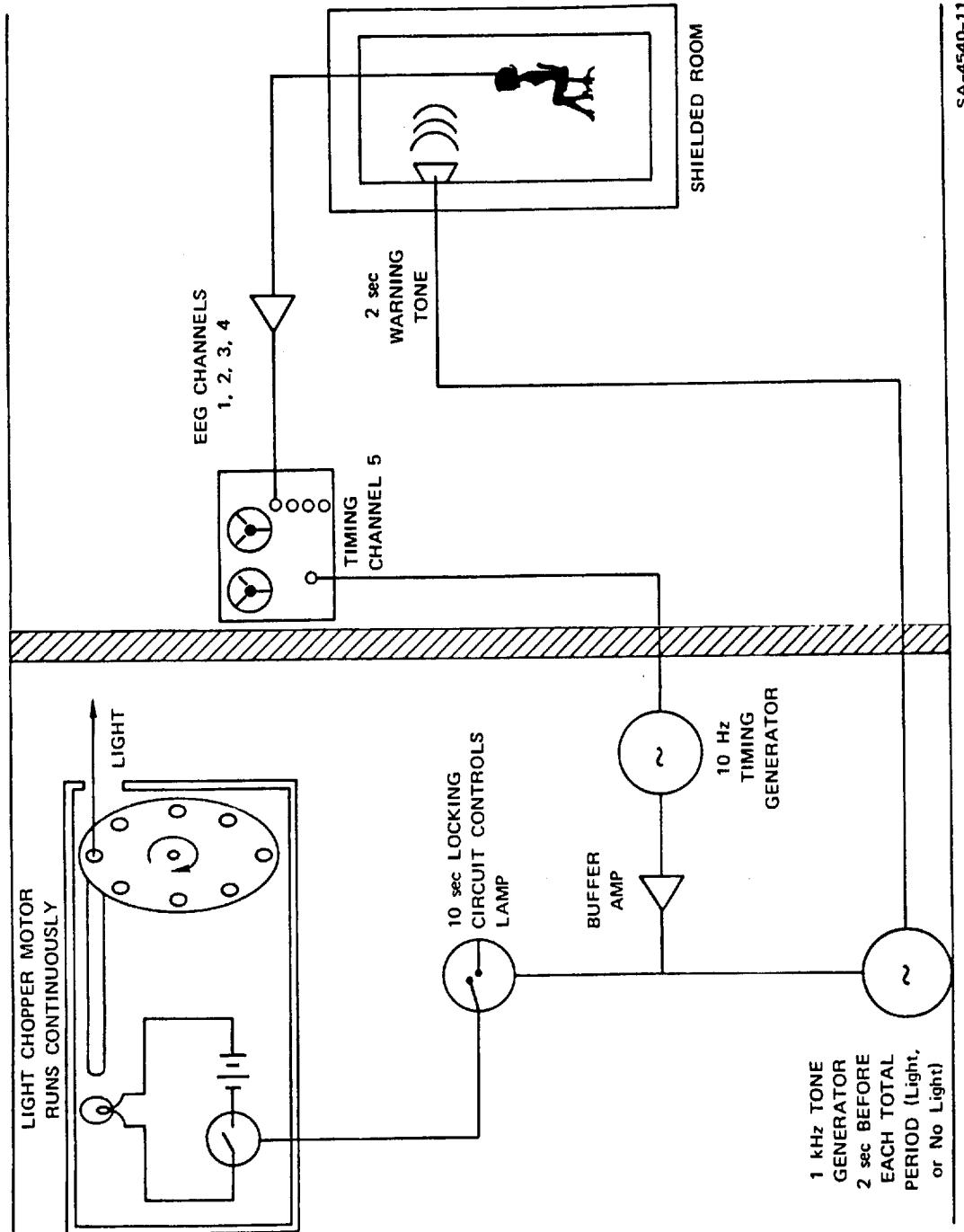


FIGURE 2 REMOTE SENSING EEG EXPERIMENT

power. To confirm that this system is equivalent to the standard FFT analysis used in the pilot study, the analog data on the entire pilot study were reanalyzed, and the result was found to be consistent with the earlier analysis.

2. Experimental Protocol

Each experimental session consisted of 40 trials, 20 each for the 0-fps (no light) and the 16-fps case of the remote light stimulus. A trial is defined as a warning tone followed by a 10-s period consisting of a 2-s wait, and two 4-s data-collection periods. The trial rate was one trial every 30 ± 1 s. The trial sequence was randomized subject to the following conditions: (1) in each group of 10 trials there were equal numbers of each condition, and (2) no more than three in a row of a single type were allowed. Seven 40-trial sequences were made according to this prescription and recorded separately on audio tape. During the session, trials were generated from one of these tapes chosen blind to the experimenters so that the sequence was unknown to them. As in standard EEG protocol, and in accordance with preestablished criteria, certain trials were deleted after the session for three reasons only: artifact, logic circuit failure, or abnormal EEG power. If a trial was rejected, a trial of the opposite stimulus condition was rejected at random from the particular set of 10 trials in question. If more than 10 trials of a given type were rejected from a session, the entire session was deleted. (This occurred twice in each of the two experiments of the study, described below.)

Six channels of EEG and one logic channel taken from the sequence tape were recorded on a multiplexed FM analog tape recorder. The logic on the tape differentiated the trials as to flashing and nonflashing conditions.

In pretesting the equipment, we ran the experiment using unselected subjects such as laboratory personnel, in order to test the adequacy of the experiment and to determine whether there were any correlated electronic or mechanical discharges from the apparatus. In

20 sessions of data acquisition, of 40 each (800 trials) there were no significant differences between the null and 16-Hz conditions. The absence of differences can also be taken as a demonstration of the non-responsiveness of the unselected subjects.

B. Results

Using the above protocol, two experiments were conducted in the course of the study, the first consisting of twelve sessions, the second, fourteen. For half of the twelve sessions in the initial experiment, the subject was asked to press a button when she felt the light was flashing. For the six sessions (105 trials each for the 0- and 16-fps conditions) when she was not asked to overtly indicate her feelings about the light, there was a slight decrease of in-band EEG power measured over the left occipital region of the brain. For the six sessions (107 trials each for the 0- and 16-fps conditions) when she was asked to respond overtly, there was a significant decrease of in-band EEG power ($p \leq 0.037$, using an F ratio test derived from a two-way analysis of variance). In considering the experiment as consisting of the combined 212 trials in each stimulus condition regardless of the overt response contingency, we find a statistically significant decrease in in-band EEG power ($p < 0.011$, using F ratio test as above).

During the second experiment of fourteen sessions, three months later, a different contingency was added to determine if a "sender" was necessary to produce the effect we had observed earlier. For a given session, a random procedure (with equal trials) was used to determine if a person (called the "sender" person) would be looking at the photo-simulator. There was no one present with the photo-stimulator otherwise. For the 7 "non-sender" sessions (121 trials each for the 0- and 16-fps conditions) we find a statistically significant increase of in-band EEG power measured over the mid-occipital region of the brain ($p < 0.039$ using an F ratio test as above). During the 7 "sender" sessions (123 trials in each stimulus condition) there was a slight increase of in-band EEG power. When all 244 trials were analyzed, regardless of "sender" condition, there was a statistically significant increase of

in-band EEG power ($p < 0.008$ using an F ratio test as above), and there was no significant difference found between "sender" and "no-sender" conditions.

For both experiments, we considered in-band EEG power for the 0-to-4-s and 4-to-8-s time periods independently, to determine if the effects were time dependent. Although some of these isolated subintervals were statistically significant, no systematic relationship emerged. Thus the effect appears to be cumulative over the 8 s. The 0-to-8-s results are summarized in Table 1.

IV DISCUSSION

Although our pilot experiment and the two replication studies all showed significant changes in EEG production correlated with the presence or absence of a remote light stimulus, the sign of the systematic change in power in the third study was opposite to that of the first two. We therefore undertook a detailed frequency analysis of the EEG data tapes from the last two experiments, since the pilot experiment had already been subjected to fast-Fourier-transform (FFT) analysis. We conjectured that the observed power change in these experiments might be the result of a very small frequency shift, which could become translated into a large amplitude change due to discriminator action of the alpha-band filter. In a chapter on alpha blocking, Kooi, in his Fundamentals of Electroencephalography says, for example, "...attentiveness is associated with a reduction in amplitude and an increase in average frequency of spontaneous cerebral potentials.... The center frequency of the alpha rhythm may be influenced by the type of ongoing mental activity. Shifts in frequency may be highly consistent as two different tasks are performed alternately." As compared with the first experiment in which the average peak EEG power fell midband, the FFT analysis for the second experiment showed that the average peak EEG power occurred most often near 8 Hz, and thus fell slightly below the hardware summing window (± 3 dB at 8.7-12.4 Hz), enhancing a possible discriminator effect. The FFT analysis further showed that there was an overall increase in frequency of peak power but the shift was statistically nonsignificant.

Table 1
 SUMMARY OF RESULTS OF THE REPLICATION EXPERIMENTS SHOWING
 POWER MEANS AND STATISTICAL RESULTS FOR THE VARIOUS EXPERIMENTAL CONDITIONS

	Experiment I			Experiment II		
	Guessing Sessions	Non-Guessing Sessions	Combined	Sender Sessions	Non-Sender Sessions	Combined
No Light flash	957	704	832	854	766	810
Light flash	873	647	761	860	844	852
F ratio	4.39	2.20	6.47	0.017	4.33	7.03
df ₁ ; df ₂	1; 202	1; 198	1; 400	1; 232	1; 228	1; 460
p ≤	0.037	0.14	0.011	0.90	0.039	0.0083

This slight shift of 0.11 Hz could possibly account for the observed power increase due to the highly nonlinear discriminator effects. In examining other portions of the spectrum for further effects, we found that systematic amplitude changes are highly dependent on the location in the frequency spectrum from which the power sum is taken. This is to be expected, since almost all EEG phenomena are known to be strongly frequency dependent.

In the pilot study the frequency region for analysis was centered about the subject's dominant EEG output frequency, with bandpass determined by the full-width ten-percent power points. In the two replication studies we used hardware filters in this same frequency. FFT analysis showed clearly that if other filter bands had been chosen, significant correlations would not have been found in some cases. Thus, although our filter selection was made before the collection of any data, other experimenters might have reasonably chosen other criteria for frequency selection. Therefore, although we have found statistically significant evidence for EEG correlates to remote light flash stimuli in all three experiments, we consider these data to be only suggestive, with a definitive result requiring further experimentation. In particular, further analysis techniques would have to be developed before any putative EEG effect could be considered as part of an information transmission/processing channel.

We wish to acknowledge the valuable contributions made to this project by SRI consultant Mr. David B. Hurt, who designed and constructed the battery powered light stimulator and logic elements used in the latter two phases of the program.

PART TWO: Langley Porter Analysis

Final Report on:

EEG STUDIES OF RESPONSES TO REMOTE STIMULATION
SRI International Subcontract No. 14157

SRI Consultants

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I INTRODUCTION

The study of perception of information despite shielding of all known sensory channels would be greatly aided if a paradigm could be devised that used a physiological response as the major dependent variable. Such a paradigm would have the advantage of not requiring verbal report or even requiring the subject's awareness of the perception. Effects of remote stimulation might be too weak to enter a subject's awareness but nevertheless be detectable as a change in some physiological index, such as the EEG. This is the case with conventional sub-liminal sensory stimulation and scalp evoked potentials.

Filtering responses to remote perception through conscious awareness must add variability to such phenomena. Removing this variability might allow the study of remote perception in a wider sample of subjects, because weaker effects may be widespread in unselected subjects, while only unusual or "psychic" subjects may be sufficiently sensitive for the remote stimulation to enter awareness. Therefore a demonstration of a reliable EEG effect would have far-reaching implications.

A paradigm that might measure EEG response to remote stimulation was devised by Drs. C. Rebert and A. Turner in cooperation with Dr. H. Puthoff and R. Targ of Stanford Research Institute. After screening six potential subjects, they identified one who seemed to produce reliable results and showed a highly monochromatic occipital EEG spectrum.

When normal subjects are stimulated with a flashing light, their EEG normally shows a decrease in the power of the alpha rhythm and a driving at the frequency of the flashes (Hill and Parr, 1963). The SRI group hypothesized that if they stimulated one subject in this manner (a sender), the EEG of another subject in a remote room with no flash present (a receiver) might show a decrease in alpha activity, and possibly EEG driving similar to that of the sender.

The SRI group showed a significant decrease of occipital alpha power in this single subject compared with control trials, in which the light did not flash (Targ and Puthoff, 1974).

We attempted to replicate their finding and to refine the technique. This was done, first by reanalyzing data tapes of their results; second, by attempting to replicate their results in our laboratory using the same subject; and finally by attempting to isolate the variables necessary to produce the phenomenon at will. We particularly examined whether it was necessary to have an observer (sender) present with the light flash stimulus and whether it was helpful to have the subject guess whether the light was flashing or not. In our second (final) experiment, we also took extreme precautions that all procedures were double-blinded, and that all previously measured electrode sites were included.

II REANALYSIS OF PREVIOUS DATA

We played the EEG tapes of Hella Hammid, gathered by Dr. Rebert of SRI, through our hard-wired alpha analysis system. The results of this reanalysis are provided in Table 1. They show power means at Oz in the null condition (no flash, 0 Hz) during the second 4-s epoch at $t = 2.08$, $p < 0.05$, $df = 119$. This reanalysis confirmed the published effect and also ensured the compatibility of our systems. This system was used in all of the experiments as well as in the reanalysis of the SRI data. The specifications and logic of our analyzer system are given below.

The amplified EEG signals are taken from the amplifier outputs and lead to the alpha EEG filters. Up to six channels can be accommodated. The filters were built by Kinetic Technology, Inc., of Mountain View, California, to high specifications: Corner frequencies 9.0 and 12.0 Hz, 48 dB down at 8.0 and 13.0 Hz with rejection over the rest of the stop-band greater than 30 dB, and pass-band ripple less than 0.2 dB p-p. The filters also had a 30-to-60-mV dc offset. Therefore, a high-pass filter with $f = 8$ Hz was designed that blocked the dc offset and satisfactorily attenuated the delta contamination, comparing adequately with alpha data generated by a fast-Fourier-transform program on our computer. Alpha levels at the filter output are usually less than 400 mV. Operational amplifiers invert and amplify the filtered alpha (gain = 50) to provide

Table 1

REANALYSIS OF DR. REBERT'S TAPES
 PLAYED THROUGH THE Langley Porter EEG ALPHA ANALYZER--
 FEBRUARY 2 THROUGH 6, 1976

Analysis of Variance with Repeated Measures

Session	Treatment			
	<u>\bar{x}0 Hz</u>	<u>N</u>	<u>\bar{x}16 Hz</u>	<u>N</u>
1:1	578	12	490	11
3:1	465	12	397	11
2:1	553	12	466	12
2:3	232	12	174	15
2:4	308	12	236	12
Mean: 427.2		340.8		

Results of t-Test

Langley Porter: $t = 2.08$, $df = 119$ $p < 0.05$
 SRI: $t = 2.09$, $df = 118$

optimum (near maximum) input to the squared circuits. The alpha signals are squared by analog multipliers (Analog Devices #533K) to yield instantaneous power, an approximation to the FFT computation. The transfer function is $X^2/10$, with a maximum of ± 10 V input yielding ± 10 V output. After this stage, the signal processing is commanded by a microprogrammed controller, hard-wired in TTL logic, except for read-only memories (ROMs) that control formatting in the digital printer. A master clock is synchronized with the power line (60 Hz).

When the experimenter is ready to begin data acquisition, he selects the summation time (1 to 99 s) with a two-digit thumbwheel switch and pushes the START button. In our experiment, two 4-s intervals were chosen. The START function resets the summing integrators, commands the

printer to print a line of special characters signifying the beginning of the record, delivers a 50-ms pulse to the polygraph marker channel, and connects the outputs of the six squaring units to the integrators. Switching is handled by reed relays for lower leakage. Solid-state switching devices were used initially, but leakage currents (10^{-9} A) were too high for the accuracy and stability required. The integrators make use of low-loss polystyrene capacitors, and FET-input amplifiers with ultra low (5×10^{-12} A) input offset current. This design makes it possible to use long summing intervals or interrupts with a drift error of no more than 1%.

After the summation time has elapsed, the outputs of the six summing integrators are sequentially connected to the analog-to-digital converter (ADC) by the analog multiplexer. When each conversion is finished (10 bits BCD) the data is parallel loaded into shift registers. The shift registers are then clocked by the controller to send the data in digit serial form to the printer. This being completed, the next integrator is connected to the ADC and the process repeats. This continues until all six integrators have been read and the summed power of each EEG lead is printed. The digital printer is a MC4000 Monroe Datalog. A fiberoptic cathode ray tube exposes light-sensitive paper quickly and (most important for our research) silently. All standard alphanumeric characters are printable.

Next, the controller commands a line feed from the printer. The second line of data for this sample consists of the log ratios of pairs of integrators representing homologous pairs of brain electrodes. The log of the ratio rather than the ratio is desired because it is linear around zero--e.g., a ratio of $2/1 = 1/2 = \pm 0.301$. The analog multiplexer is then commanded to connect the first two integrators to the two inputs of the log ratio module. Its output is an analog voltage representing the log ratio of the two channels to a 10-bit BCD number. The printing process is the same with the addition of a polarity bit indicating which hemisphere has a higher output for the task.

The process is repeated for computation of log ratios of the other two pairs of integrators. After the last data are printed, the controller resets the integrators, then reconnects the squaring units to their integrators. One count is added to the trial display register, which tells the experimenter at a glance how many epochs have been collected. The digitizing, computation, and printout takes 2 s, primarily due to the switching speed of the relays.

III FIRST EXPERIMENT AT LANGLEY PORTER: ATTEMPTED REPLICATION OF SRI STUDY

A. Method

1. Subject

The first experiment was conducted with a single subject, Hella Hammid, who had been selected from an initial group of four female and two male subjects tested by the SRI group. She was selected because she had had the most consistent positive results in their study.

2. Setting and Procedure

The first experiment was conducted in our EEG laboratory at Langley Porter Institute. The setting is diagrammed in Figure 2 in Part One of this report. The "sender" sat before the photic stimulator in a divided room separated by a curtain from the logic, equipment, and monitors. The number of people in the room with the stimulator and the "sender" varied from one to three. Noise from the street and hallway also varied.

The "receiver" sat upright in an isolated sound-attenuated darkened metal chamber located in a laboratory adjacent to the room in which the sender was located. The "receiver" (subject) made no overt responses for Set 1, but was required to press a button to indicate her guess of trial type about 12 s after the warning tone for Set 2. The subject was familiar with the nature of the experiment, and was not formally instructed for each session.

The sender and receiver were both presented with a one-second warning tone that signalled the beginning of a trial. This was immediately followed by the light flashing for 10 s at 16 Hz in the active condition, and by no flashes in the null condition. The stimulation period was divided into 4-s segments for comparability with the Rebert study; the first 4 s following flash onset (or null onset), and the second 4 s starting with the sixth second from onset. (The fifth second was blocked from the analyzer by the print cycle, and we discarded the tenth second.) A "set" was defined as at least 100 acceptable trials of each type. After the first set, minor modifications (such as a button to indicate guesses) were added, and a second set was run. The total number of acceptable trials was 212 of both types, or 424 total.

In pretesting our equipment and procedure we used unselected subjects such as laboratory personnel, in order to test the adequacy of the protocol and to determine whether there was any correlated electronic or mechanical interference from the apparatus. In these pilot sessions of data acquisition there were no significant differences between the null and 16-Hz conditions.

3. EEG Recording Procedure

Electrodes were placed at C3, C4, O1, O2, and Oz, all referenced to Cz. The occipital leads were not identical to the montage used by the SRI group (Oz referenced to linked mastoids), but our montage was used to provide more information about localization within the occipital region, hemispheric specialization, and possible related activation at other leads.

The EEG output (J6) of the Grass model 7 polygraph was sent to our data analysis system, described above, and also to a Hewlett Packard FM tape recorder, through a Vetter multiplex system. The FM tape provided the capacity for any possible future reanalysis.

4. Editing

The hard-copy EEG output from the polygraph was edited for artifact by experimenters blind to the stimulus conditions of any

trial. Any trial showing evidence of electrode slippage or of EMG or EOG contamination, was deleted from the data set.

Trials were deleted after the session for three reasons only: EEG artifact, logic circuit failure resulting in a breakdown in the trial sequence, or out-of-range EEG power (under 50 or above 1299 on printout). In each case, the linked (or previously paired trial of any trial discarded was also discarded along with data from all leads for all 8 s. If more than 10 trials altogether were deleted for any session of 40 trials, the session was deleted. Only in the case where it would make the difference in saving or discarding a session were the tapes of the session played back and reanalyzed at different gain levels to recover out-of-range epochs. This was done for three sessions.

5. Stimulus

The stimulus was a battery-driven, continuous-wattage incandescent lamp, chopped by a continuously rotating apertured disc. When the lamp was lit, the visible stimulus was a 16-Hz flash. In null trials the lamp was not lit. The stimulus was stationed in a remote room approximately 10 m from the subject.

6. Control of Stimuli

The trials in the experimental sessions were triggered by pulses from one of a set of several tapes so that no human operator was involved in the triggering of the trials in either the 16-Hz or the 0-Hz condition (once the session had begun). These tapes were made at our laboratory during the month preceding the experiment.

Randomized tables for the tapes were generated with a Texas Instrument SR-51A electronic random-number generator. Random sequences of +s (16 Hz) and -s (0 Hz) in lengths of 40 were generated, constrained by the requirements that: (1) the trials be pseudorandomized within each block of 10 trials (i.e., groups 1-10, 11-20, 21-30, and 31-40 each contain five of each kind of trial); and (2) not more than three trials in a row of either type be allowed.

The following procedure was used: +s and -s were assigned alternately within each block of 10 trials according to the random sequences of numbers generated by the key. For example, if the 21-30 block was being filled, and the random sequence of numbers was 14, 38, 45, 27: first a + would go to 1, then a - to 4, then + to 3, - to 8, + to 5, - to 2, + to 7, etc., until the block was filled, and then on to the next block (repeated digits were ignored). Furthermore, each + and the succeeding - were linked in the record for editing purposes (see above).

Blocks of +s and -s were discarded if it was clear that they would include sequences of four or more consecutive +s or -s; also, if a sequence of four or more +s or -s was created from the juxtaposition of two blocks of 10, the latter block was reversed (+s changed to -s, and vice versa). A single block of 10 trials was discarded because of calculator failure in the middle of generating the block, and another was discarded because of a possible recording error on the part of the operator; otherwise each trial that was generated was kept.

Control signals for trials were recorded on a tape with a 4-track Ampex stereo FM tape deck in direct mode, with pulses on one channel for the 16-Hz condition and on another for the 0-Hz condition. The pulses were produced by two Grass stimulators. They were recorded 30 s apart, then checked afterward on playback. The inter-trial interval was checked and found to be within 1 s of 30 s, consistently, with no detectable systematic difference between conditions. The tapes were played back on a Tandberg two-track stereo tape recorder into a logic circuit that triggered the type of trial corresponding to the channel. There were only rare failures in trial triggering due to errors in the trial tapes at any point during the experiment.

The coded tapes were selected by number with no pre-arrangement except that a different tape be used for each session in a set until all tapes were used once. Only the operator of the logic equipment had the knowledge of which tape was being used, and no person knew before any trial what the trial type would be: that information was coded in the tape. The coded tapes produced 5-V pulses which, mediated by the digital logic, triggered the appropriate stimulus type

for any trial. Inter-trial interval was fixed by the spacing of pulses on the tape to be 30 ± 1 s. The command box of the photic stimulator, when triggered, produced a 1-s warning tone to both sender and receiver and, following another 1-s interval, flashed a light for 10 s when a 16-Hz trial was ordered, or did nothing if a null trial was ordered. The digital logic sent pulses to turn the analyzer on and off at 1 s and 10 s, respectively, from the onset of the trial. For each trial the digital logic generated timing pulses to be recorded on the Hewlett Packard tape for use, if necessary, in off-line computer analysis of the data. A 16-Hz trial was differentiated from a 0-Hz trial by the presence of an initial 0.5-V positive pulse for the 16-Hz trial. This was the only electronic signal differentiating the two conditions, that entered the recording area while the experiment was in progress. Operators in the recording area did not monitor this signal.

B. Results

The means of summed alpha power in arbitrary relative power units are presented in Table 2. The differences found to be significant at greater than 0.05 are starred. Significance levels were assigned by F-tests from repeated measures of analyses of variance. The analyses of variance were performed separately for each lead and epoch and repeated across condition means.

The SRI experiment reported a decrement at Oz-linked mastoids at 16 Hz compared with the null condition, in the second 4 s. At our Oz-Cz lead we did not find a change in the second 4 s of either set, but did find a significant decrement in the first 4 s of the first set. None of the other Oz comparisons attain significance and the combined Set 1 and Set 2 first 4 s is not significant. Therefore we did not specifically confirm the SRI findings. However, O1 and O2 showed significant decrement in the first 4 s of Set 1, and O1 showed enough decrement to reach significance in the last 4 s in Set 2, and in all 8 s, with both sets combined. Because our electrode montage was not identical with the SRI montage, our first experiment showed some decrements at other locations.

Table 2

FIRST EXPERIMENT AT Langley Porter:
 MEANS OF SUMMED EEG ALPHA IN RELATIVE-POWER UNITS,
 EXPRESSED AS NULL CONDITION/16-Hz CONDITION

		Lead					
		Set 1	C3	C4	O1	O2	Oz
Epoch	0-4 s	276/261	276/245	353/305*	425/336**	419/352*	
	4-8 s	284/267	268/249	358/347	415/413	420/413	
	0-8 s	560/528	544/494	711/655	841/749	839/765	
	<u>Set 2</u>						
Epoch	0-4 s	305/288	389/386	469/461	534/536	532/563	
	4-8 s	303/274	411/371	479/419*	511/477	484/516	
	0-8 s	608/562	800/757	948/880	1045/1013	1015/1079	
	<u>Combined Set 1 and Set 2: O1 Only</u>						
Epoch	0-4 s			411/383			
	4-8 s			419/383*			
	0-8 s			830/766*			

* Significant at $p < 0.05$.

** Significant at $p < 0.01$.

IV SECOND EXPERIMENT AT Langley Porter: ATTEMPTED REFINEMENT

Since the data from the SRI study and our first one were compatible if not identical, we decided to continue to explore possible sources of variance in this phenomenon. Specifically, we pursued the dependence upon the "sender" and the possible importance of a trend for the trials in which the subject correctly guessed that the light was on or off to show the greatest EEG power differences. In addition, we examined the differences between our montage of EEG sites (O1, O2, C3, C4 ref. Cz) and the SRI montage (Oz to linked mastoids); and used more careful procedures ensuring double-blinding of experimenters and subject.

A. Method

1. General

The method was the same as in the previous experiment, although carried out in a new location (see Figure A-1 in the Appendix), and with the addition of several refinements. Sessions with a "sender" alternated with sessions without a "sender". The subject was also given a "pass" or no-response option, so that she could indicate when she did not feel sure of her response and would not hazard a guess about the stimulus condition. The pass option was signaled by the subject pushing a button that marked the polygraph record, so that we could discriminate guess trials from non-guessed ones. There was an additional EEG channel used, so that in addition to recording from O1, O2, C3, C4, and Oz referenced to Cz, as in our first experiment, we also recorded the Oz referenced to linked mastoids configuration used by the SRI group.

The subject ("receiver") was again Ms. Hammid, and the "sender" was always R. Targ.

2. Double-Blind Procedures

In addition to generating the stimulus-condition sequence types, we ensured that no one had information concerning the trial-type sequence. The person who generated the tapes gave them to another member of the laboratory staff for labeling: A, B, C, etc. A third staff member chose a tape at random before the session. No one had knowledge of the trial-type sequence until after the session was completed and the stimulus marker sequence played back from the Hewlett-Packard recorder. The operator who played the tape coded the trial-type neutrally (i.e., A and B rather than + and -). The operator who did this step knew the code and was not allowed to handle data further. The personnel who analyzed the data were blind to which of the two labeled conditions corresponded to the actual trial-type.

The trial-type was monitored with a light-sensitive recorder--i.e., no one was in the room during trials without a "sender". During "no-sender" sets, Mr. Targ spent the duration of the set with one

of the experimenters. He did not know in advance whether a given set would be "sender" or "no-sender."

B. Results

1. General

The means of summed alpha power are presented in Table 3 and Table 4. Table 3 lists the means from all trials, showing the trials with a sender separately from those without a sender. Table 4 shows the means from only those trials on which the subject guessed the stimulus condition. Significance levels were again assigned from F-tests from repeated measures of analyses of variance performed separately for each lead, repeated across condition.

This experiment shows an effect opposite that of the SRI experiment and our first study: instead of alpha power decreasing during the active condition, it increased. The effect reaches significance only at Oz referenced to Cz, although the direction is the same at other leads. Also of interest is the finding that for the SRI montage, Oz referenced to linked mastoids, there was no significant difference between stimulus conditions. The only F-value to reach the 0.05 level is that of Oz referenced to Cz ($F = 4.33$), no sender. If this is combined with the trials with sender (which is not significant by itself-- $F = 2.647$), the overall F for 0-8 s is 7.03, $p < 0.01$. However, this is a different site than that used for the original SRI finding, and our first experiment, and in the opposite direction.

2. Guess Effect

For trials in which the subject was required to guess the stimulus condition (guess trials), our first experiment showed a tendency to exhibit a greater alpha decrease than in trials in which the subject did not guess. Trials in which the subject correctly guessed the stimulus condition showed this tendency to a greater degree. We investigated this tendency more rigorously in the second experiment.

Table 3

SECOND EXPERIMENT AT Langley Porter:
 ALL TRIALS, SENDER VS NO SENDER MEANS AND F VALUES
 OF SUMMED EEG ALPHA IN RELATIVE POWER UNITS,
 MEANS EXPRESSED AS NULL CONDITION/16-Hz CONDITION
 (Seven Sessions, 121 Trials in Each Condition)

		Lead				Oz to Linked Mastoids		
		01	02	C3	C4	Oz		
<u>Sender--All Trials</u>								
Epoch	F Values	0-4 s	0.073	1.687	0.041	0.744	1.071	0.182
		4-8 s	0.039	2.556	0.032	0.000	1.221	0.024
		0-8 s	0.089	3.853	0.107	0.116	2.647**	0.017
	Means	0-4 s	479/486	484/517	275/264	320/306	408/439	439/449
		4-8 s	428/432	441/480	253/255	280/281	384/410	415/410
		0-8 s	907/919	925/997	527/519	595/586	792/849	854/860
<u>No Sender--All Trials</u>								
Epoch	F Values	0-4 s	2.760	1.560	1.912	0.902	2.750	0.364
		4-8 s	0.374	0.541	0.046	1.020	2.440	0.700
		0-8 s	2.090	1.869	0.611	0.001	4.330*	0.770
	Means	0-4 s	404/442	401/491	262/284	335/318	382/423	499/521
		4-8 s	399/411	441/461	271/267	297/314	385/422	466/498
		0-8 s	802/853	902/952	533/551	633/632	766/844*	966/1018

* Significant at $p < 0.05$, $F > 3.93$ (1, 120).

** Significant at $p < 0.01$, $F > 6.84$ (1, 120).

Table 4

SECOND EXPERIMENT AT Langley Porter:
 GUESS TRIALS ONLY, SENDER VS NO SENDER
 MEANS AND F VALUES OF SUMMED EEG ALPHA IN RELATIVE POWER UNITS,
 MEANS EXPRESSED AS NULL CONDITION/16-Hz CONDITION

		Lead					Oz to Linked Mastoids	
		01	02	C3	C4	Oz		
<u>Sender--Guess Trials</u>								
Epoch	F Values	0-4 s	0.003	0.470	0.642	1.081	0.833	0.017
	Means	4-8 s	0.312	0.676	0.005	0.002	0.097	0.758
		0-8 s	0.083	1.058	0.330	0.402	0.614	0.422
Epoch	F Values	0-4 s	489/491	495/514	268/253	318/300	415/438	450/447
	Means	4-8 s	445/432	461/482	258/257	284/285	400/408	436/408
		0-8 s	934/922	956/997	525/510	602/585	815/846	886/855
211 Trials: 104 null, 107 16 Hz								
<u>No Sender--Guess Trials</u>								
Epoch	F Values	0-4 s	1.900	0.752	1.182	1.638	1.894	0.044
	Means	4-8 s	0.344	0.490	0.013	0.563	1.755	0.901
		0-8 s	1.603	0.840	0.663	0.168	3.069	0.533
Epoch	F Values	0-4 s	413/447	475/498	261/278	340/314	387/423	512/520
	Means	4-8 s	408/420	451/469	270/272	301/314	392/426	481/519
		0-8 s	820/868	928-963	531/550	641/628	779/849	993/1040
211 Trials: 106 null, 105 16 Hz								

The "pass option," described above, to eliminate forced guessing when the subject was not certain, made it less likely that incorrect guesses would be included.

Comparison of Table 4 to Table 3 shows that the effect of guessing certainly does not increase the effect noted at Oz. Alpha increases in the active condition compared to the null condition were not significant. The logical inference of this is that the pass trials should show a greater difference than "guess" or "all" trials. Table 5 shows the pass trials. They do exhibit greater differences in the same overall direction of this experiment, an alpha increase in the active

Table 5
SECOND EXPERIMENT AT LANGLEY PORTER:
PASS TRIAL MEANS,
SHOWN AS NULL CONDITION/16 Hz CONDITION

		Lead: Referenced to Cz						
		01	02	C3	C4	Oz	Oz to Linked Mastoids	
<u>Sender--Passes</u>								
Means	Epoch	0-4 s	420/468	423/523	316/356	328/344	353/454	403/440
		4-8 s	360/427	331/475	227/256	268/246	301/428	308/406
		0-8 s	780/895	754/998	543/612	596/590	654/882	711/846
Ratios of Means	Epoch	0-4 s	0.90	0.81	0.89	0.95	0.78	0.92
		4-8 s	0.84	0.70	0.89	1.09	0.70	0.76
		0-8 s	0.87	0.76	0.89	1.01	0.74	0.84
<u>No Sender--Passes</u>								
Means	Epoch	0-4 s	366/382	393/417	277/307	321/323	345/399	364/516
		4-8 s	357/343	393/378	269/206	299/315	303/397	333/374
		0-8 s	723/725	786/795	546/513	620/638	648/796	697/890
Ratios of Means	Epoch	0-4 s	0.96	0.94	0.90	0.99	0.86	0.71
		4-8 s	1.04	1.04	1.31	0.95	0.76	0.89
		0-8 s	1.00	0.99	1.06	0.97	0.81	0.78

condition, opposite to what was seen in the first study. Further post-hoc statistical tests were not performed on the pass trials because the differences were clearly too small to reach significance. A very conservative criterion is required for a post-hoc analysis of an isolated observation for which there are previous data in the opposite direction.

The second factor in the trend toward a guess effect in the first experiment was an even greater alpha difference on those trials in which the subject guessed correctly. The correct guesses for the second experiment are shown in Table 6. The correct guesses without a sender show a small alpha increase in the active condition compared to

Table 6

SECOND EXPERIMENT AT LANGLEY PORTER:
CORRECT GUESS TRIAL MEANS,
SHOWN AS NULL CONDITION/16-Hz CONDITION

		Lead: Referenced to Cz						
		01	02	C3	C4	Oz	Oz to Linked Mastoids	
<u>Sender--Correct Guesses</u>								
<u>Means</u>	Epoch	0-4 s	518/463	561/497	291/233	348/276	463/407	481/445
		4-8 s	465/429	473/492	277/236	303/292	417/407	387/459
		0-8 s	983/892	1034/989	568/469	651/568	880/814	868/904
<u>Ratios</u>	Epoch	0-4 s	1.12	1.13	1.25	1.26	1.14	1.08
		4-8 s	1.09	0.96	1.17	1.04	1.02	0.84
		0-8 s	1.10	1.05	1.21	1.15	1.08	0.96
<u>No Sender--Correct Guesses</u>								
<u>Means</u>	Epoch	0-4 s	425/449	469/505	284/256	356/298	386/420	529/540
		4-8 s	421/411	456/453	302/262	331/306	394/406	496/585
		0-8 s	846/860	925/958	586/518	687/604	780/826	1025/1125
<u>Ratios</u>	Epoch	0-4 s	0.94	0.93	1.11	1.19	0.92	0.98
		4-8 s	1.02	1.01	1.15	1.08	0.97	0.85
		0-8 s	0.98	0.97	1.13	1.14	0.94	0.91

the null condition (not significant). Correct guesses with a sender show a small alpha decrease compared to the null condition, in the direction of the first experiment, but too small to be significant.

V DISCUSSION

In two studies, one at SRI and one in our laboratory, a decrease in EEG alpha power was observed as a function of remote photic stimulation, but at different scalp locations and in different time periods following the stimulus onset. The third study, on our laboratory, showed an increase in alpha power at another site and failed to replicate the original finding.

Dr. Edwin May of SRI has done a full power spectral analysis of these data and reports that his analysis shows results similar to ours. We also observed that the subject's alpha frequency seemed to be slightly lower in the second experiment than the first, and Dr. May's analysis confirmed this. However we see no easy way to account for the negative or inconsistent experimental results in terms of frequency changes. We cannot account for this frequency change. The subject underwent major pelvic surgery in the three months between our first and second experiments, but there is no apparent reason to relate this to the EEG change.

Statistical analysis of these data necessitated many significance tests on the same subject. One must always question the independence of such tests, and also keep in mind that 5% of them will be significant if the 0.05 level of confidence is adopted. In addition, repeated measures on one subject and simultaneous measurements from different leads always brings the independence of these measures into question.

If the findings were replicable, the statistical questions would be less important. However, since there are many possibilities and we failed to replicate either our earlier finding or the SRI results, it is necessary to take a more conservative statistical position. The three separate experiments all show effects in the occipital cortex, but it is not the same effect, either in direction or site. We believe the

three experiments should not, therefore, be lumped together as jointly supporting each other: They could just as easily be taken as jointly nullifying each other.

In conclusion, on each occasion, alpha changes occurred that differ from chance, but we could not reproduce the same effect, in either direction or site. There remains the possibility that a useful phenomenon exists here, but if so, we have clearly not isolated the variables necessary to produce it at will.

Appendix

SRI OPTICAL ISOLATION EXPERIMENTS AT Langley Porter

Appendix

OPTICAL ISOLATION EXPERIMENTS AT Langley PORTER

1. Introduction and Summary

As described in Sections I-B and III-A of this report, the purpose of these measurements was to determine whether there exists any measurable light leakage between the stimulus room in which a chopped light source operates, and the subject room in which EEG recordings are being made.

Using phase-sensitive detection, a photomultiplier with an S-20 photocathode, and a synchronously chopped light source, we obtained a system sensitivity of 5×10^{-15} W/cm² with unity signal-to-noise ratio, limited by photo-tube dark current. This sensitivity, in W/cm², is 3×10^{-13} of the flash lamp intensity used in our experiments (125 dB down). Our findings using this equipment are as follows:

- (1) In order to obtain a measurable light leakage signal it was necessary to open two of the three doors separating the stimulus room from the subject room (see Figure A-1) and direct the output of the flash lamp on the door frame of the subject room. Under these conditions a signal could be detected with 20:1 signal-to-noise ratio by the photomultiplier placed in the subject chair.
- (2) When any two of the three doors between the subject room and the flash lamp were closed, no signal could be detected, up to the measuring capability of the apparatus, with a 10-s integration time.
- (3) To examine the possibility of light transmission through the air conditioning ducts, we placed the photo-tube detector in the duct in the subject room and directed the output of the flash lamp on the duct in the stimulus room. Again, no detectable signal was found.

From this investigation we find that to the limit of our measurement capability and under the conditions defined by the experimental protocols and geometry, there was no light leakage between the rooms in question; thus we conclude that the experimental findings of this program cannot be attributed to light leakage.

2. Laboratory Arrangement

The laboratories evaluated in this experiment consist of two groups of rooms on either side of a hallway. (See Figure A-1.) The doors of the two laboratories face each other as they open onto a hall. The stimulus room housing the lamp is a single room with one door. The subject room is entered from the hall, by first passing through a control room housing EEG recording equipment. The subject room is considered a darkroom, and has windows on the outer wall (opposite the control room) that are taped and boarded up. A small but visible amount of light enters the room around the tape. The room is separated from the control room by a wooden door having plastic weather stripping on its edges, as have the outer doors of both labs. Thus, from where the subject sat in the dark room, the light from the stimulus room would have had to pass through three closed and sealed doors to reach her.

3. Apparatus

The light-detecting system used in this measurement is shown in Figure A-1. An electron multiplier photo-tube (RCA 7265) is powered by an 1800-V dc power supply, and its anode current is measured across a 100-kilohm resistor. The voltage thus developed goes to the input channel of a PAR (Princeton Applied Research) phase-sensitive detector, having a tuned input filter, phase-sensitive amplifier, and variable time constants. We derive the reference signal for the amplifier from a small photodiode taped to the face of the chopped light source in the stimulus room. The chopping frequency is 16 Hz.

The output of the light source was measured with a 16-junction Eppley thermopile and a microvoltmeter. This measurement gave an intensity of 15 mW/cm^2 at 10 cm from the light source.

Using this now-calibrated light source, together with calibrated neutral density filters, we measured the sensitivity of the phototube and phase-sensitive detector to be $5 \times 10^{-15} \text{ W/cm}^2$, with an integrating time constant of 10 s.

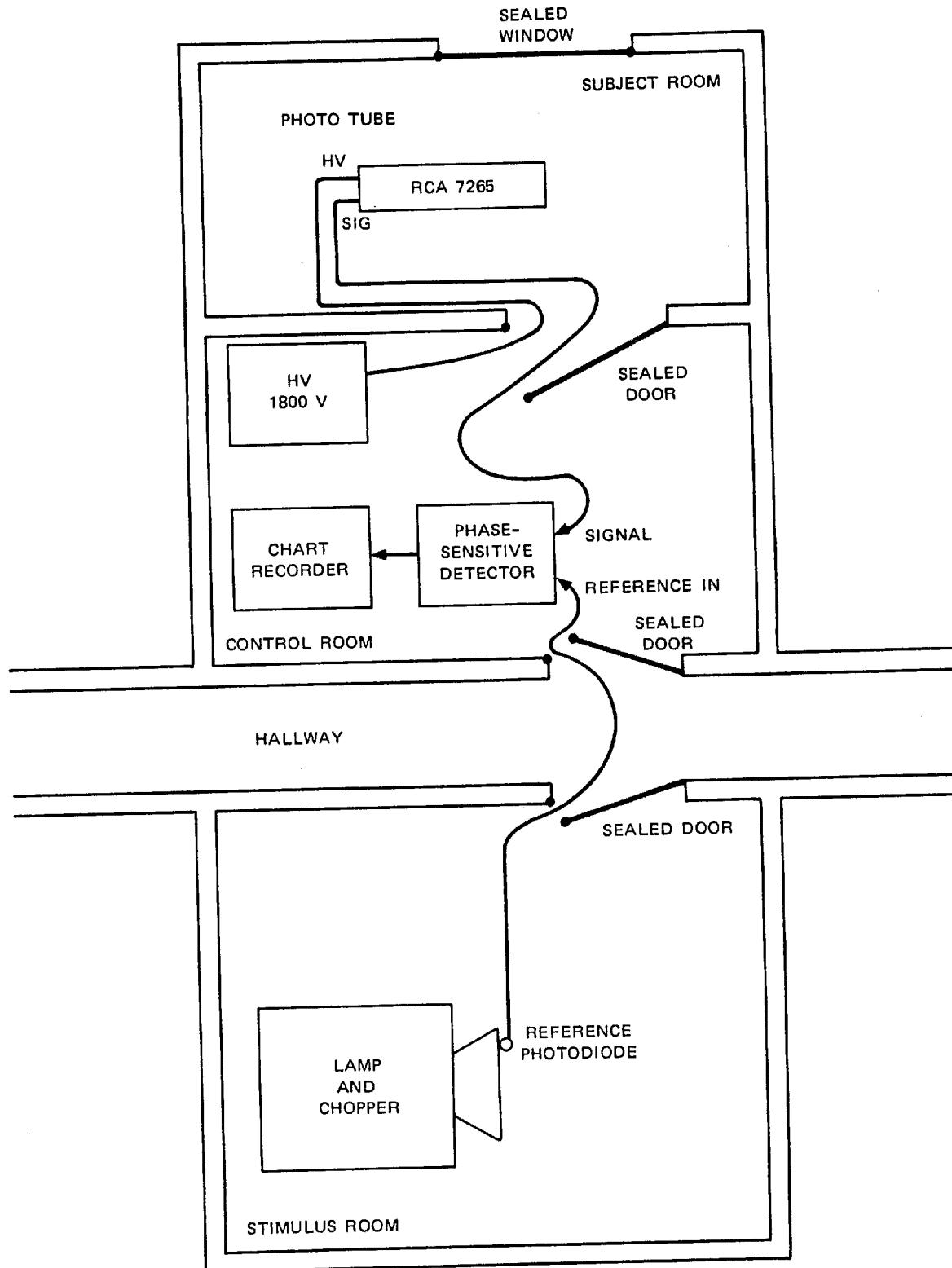


FIGURE A-1 FLOOR PLAN AND APPARATUS FOR LIGHT-LEAKAGE MEASUREMENTS

4. Results

In these experiments the conditions were exactly as they were during the actual EEG experiments described in detail in Section IV-A of Part 2 of this report. In particular, there was a small amount of outside daylight leaking into the subject room through the electrical tape used to seal the window cracks. This was quite a small amount of light, amounting to approximately six times the dark current of the phototube--i.e., $3 \times 10^{-14} \text{ W/cm}^2$. This amount of light is barely detectable to the dark-adapted eye, but does give rise to incoherent shot noise in the phototube, increasing the magnitude of the minimum detectable signal.

The subject room and the light stimulus room are connected to a common air-conditioning system. The air-conditioner ducts make eleven right-angle bends in traversing the 30 feet between the two rooms, and this ducting was a prime suspect for possible light leakage between the two rooms. To determine the presence of such leakage, the phototube was placed inside the duct in the subject room, and the light stimulator had its output directed at the duct in the stimulus room (even though this was not the condition during actual experiments, when it was pointed toward the side wall of the room). With the phototube in the duct, its background was no longer determined by the ambient light in the room, but rather by phototube dark current, giving a phase-sensitive amplifier reading of $5 \mu\text{V}$, corresponding to $5 \times 10^{-15} \text{ W/cm}^2$. This signal was not affected by the presence or absence of light from the flash lamp directed at the other end of the air-conditioning duct.

In measurements with the flash lamp directed along a vector across the intervening hall toward the door frame and closed door of the experimental room, no position or manipulation of the flash lamp produced any effect whatever on the output of the phase-sensitive detector. A signal could be detected only when both of the two hall doors of the laboratory rooms were left open to allow the light to leave and enter the rooms (a condition counter to those set up during experimentation). The signal in this case was twenty times the shot noise background due to ambient light in the darkroom, with its door closed.